

Discussion on possibility of early film collapse for corium particles during FCI based on experimental results from unexpected collision between solid sphere and thermocouple

KHNP CRI^a, KAIST^bSeung Hyun Yoon^{a*}, Hee Cheon NO^b, Yu jung Choi^a

Introduction

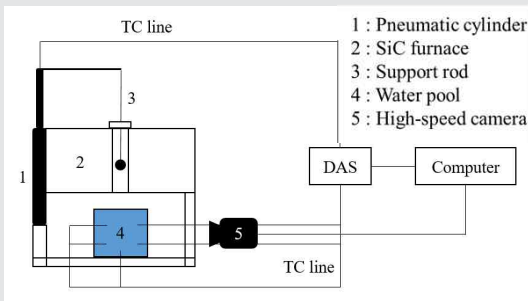
Film boiling heat transfer

- Film boiling is formed with the high temperature corium (~3000K) interacting with a water
- Typically, the collapse of the film boiling occur at the minimum film boiling temperature
- Previous studies with the pressure shock reported the behavior that the film boiling breaks instantly and recovers the film boiling regime back
- However, the early and complete collapse of the film boiling was observed in this paper
 - Caused by the unintentional collision between the sphere specimen and the thermocouple installed in the water pool

Method

Test apparatus

- Heated specimen in the furnace drops to the water pool and collides with TC



Conditions

- “Fast” in Quenching mode indicates the complete collapse of the film boiling in an early time
- “Slow” in Quenching mode means that the film boiling sustained until the specimen temperature reached the minimum film boiling temperature

Test #	Initial sphere temperature °C	Initial water temperature °C	Quenching mode
1	946.25	25.8	Fast
2	936.72	28.6	Slow
3	927.35	30.8	Fast
4	929.19	32.5	Fast
5	933.94	34.1	Fast
6	919.47	35.5	Slow
7	922.06	36.9	Slow
8	926.62	37.8	Slow
9	918.86	38.7	Slow
10	926.08	39.5	Slow
11	930.02	40.2	Slow
12	927.15	40.8	Slow
13	926.19	41.4	Fast
14	927.40	41.9	Slow
15	921.13	42.6	Fast

Heat transfer calculation

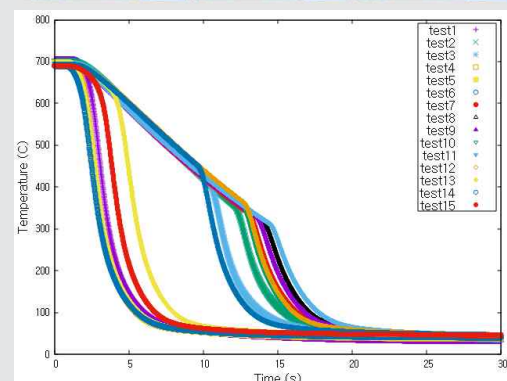
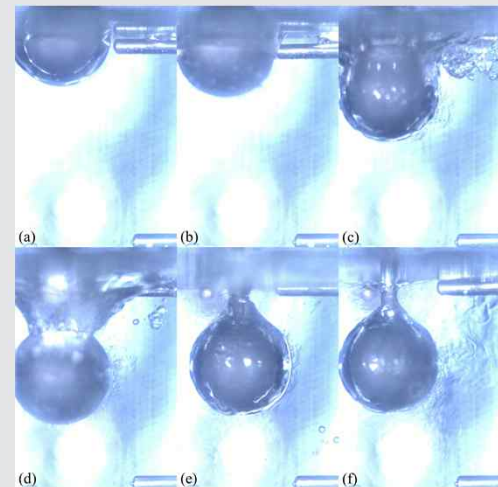
- Heat flux and heat

$$q''_{\text{total}} = \frac{Q_{\text{total}}}{\pi D_{\text{sphere}}^2} \quad Q_{\text{total}} = m_{\text{sphere}} c_p \frac{dT_{\text{sphere}}}{dt}$$

Results

Observations (500 ~ 1000 fps)

- Test #15 (Quenching mode : Fast)
 - (a): right before the contact between the sphere and the TC
 - (b): instant film breakup at the collision
 - (c): recover of the film boiling
 - (d): instant film collapse again at the lowest position
 - (e): recover the film boiling and sustained the state about 1.36 s
 - (f): beginning of the complete collapse of the film boiling at relatively early time compared to other test cases
- The fast and slow quenching behaviors did not depend on the instant film breakup
 - Test #12 showed the slow quenching with (d) photo
 - Test #13 showed the fast quenching without (b) and (d)



Conclusions & Acknowledgement

- The early collapse of the film boiling was observed by the collision between the specimen and the TC
- This may occur and enhance the heat transfer during FCI with such situations: 1) the solidified corium meets with the cavity bottom, 2) the solidified corium interacts with the pressure wave generated by the steam explosion
- This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) grant funded by the Korea government(MOTIE) (20193110100050)